Contents

[GENERATIVE AI – IN DETAILS 2](#_Toc204524639)

[GENERATIVE AI VS DISCRIMINATIVE AI 2](#_Toc204524640)

[LARGE LANGUAGE MODELS(LLMs) 4](#_Toc204524641)

[HOW ENCODERS FIT IN? 5](#_Toc204524642)

[HOW DECODERS FIT IN? 6](#_Toc204524643)

[CORE COMPONENTS OF LLMs 7](#_Toc204524644)

[HOW LLMS WORK 9](#_Toc204524645)

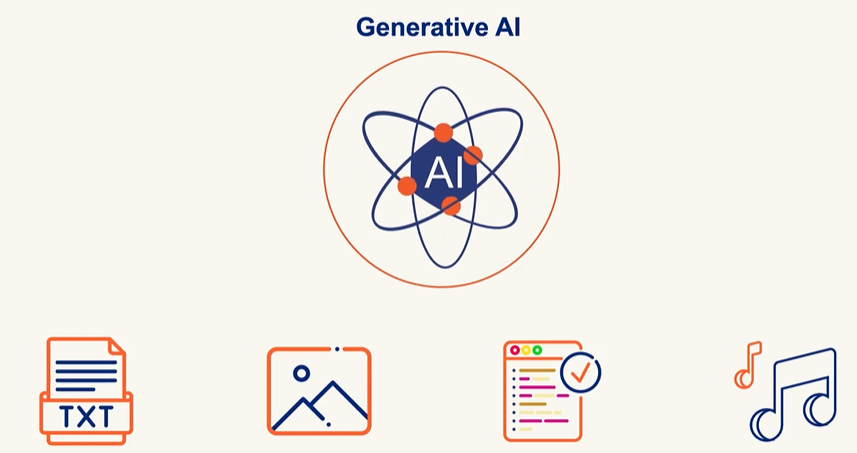
[MODEL TYPES (LLM TYPES) 13](#_Toc204524646)

[EMBEDDINGS IN GENERATIVE AI 17](#_Toc204524647)

[FINE TUNING 18](#_Toc204524648)

# GENERATIVE AI – IN DETAILS

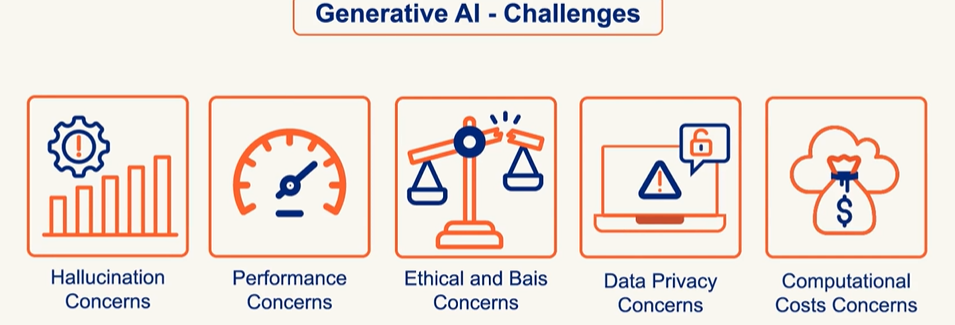
WHAT IS GENERATIVE AI



Generative AI creates new content like Text , Image , Audio and Code based in learned Pattern unlike Traditional AI which classifies and predict

* Artificial Neural Network (ANN) is the foundation of Generative AI. It’s a type of machine learning model inspired by the structure and functioning of the human brain

GENERATIVE AI CHALLENGES



## GENERATIVE AI VS DISCRIMINATIVE AI

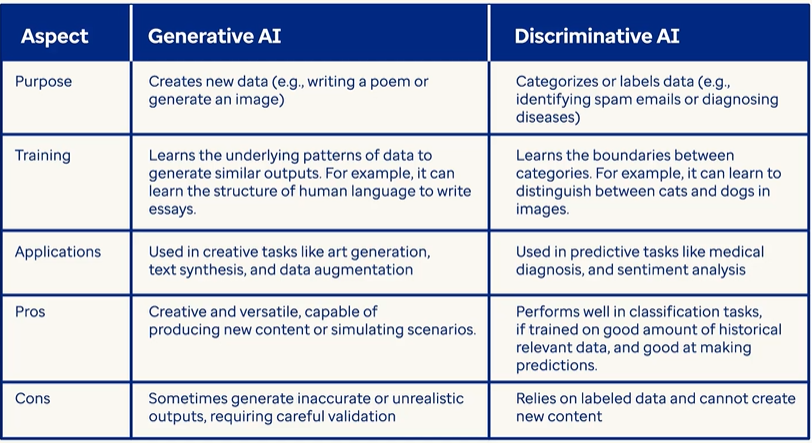
* **Generative AI models** learn the **joint probability** of inputs and outputs (P(x, y)). This means they understand how data is structured and can **generate new data** that looks similar to what they’ve seen.



* **Discriminative AI models** learn the **conditional probability** (P(y|x))—they focus on **distinguishing** between different categories or classes. Its goal is to **classify** or **predict** based on input data.
* Example:
  + **Spam filters** classify emails as spam or not spam.
  + **Face recognition systems** identify people from images.
  + **Sentiment analysis** detects if a review is positive or negative.

A logo with blue and orange squares

AI-generated content may be incorrect.



Artificial Neural Networks (ANNs)

A diagram of a diagram

AI-generated content may be incorrect.

An ANN is made up of layers of **nodes (neurons)**:

1. **Input Layer** – Takes in the raw data/features (e.g., pixels of an image, words in a sentence).
2. **Hidden Layers** – Perform computations and extract features. There can be one or many of these.
3. **Output Layer** – Produces the final result (e.g., classification, prediction, generated content).

Input Layer – Where It All Begins

* This is the **first layer** of the network.
* It receives **raw data** like numbers, images, or text.
* The data is broken into **features** (e.g., for predicting apartment price: size, number of rooms, location).
* Each feature becomes an **input node** in the network.

Hidden Layers – The Brain of the Network

* These are the **intermediate layers** between input and output.
* They **process the input data** and extract deeper patterns or sub-features.
* More hidden layers = more ability to learn **complex relationships** in the data.

Output Layer – The Final Decision

* This layer gives the **final result** of the network.
* Depending on the task, it could:
  + Classify (e.g., spam or not spam),
  + Predict (e.g., apartment price),
  + Generate (e.g., new text or images).

Connections and Weights – How Learning Happens

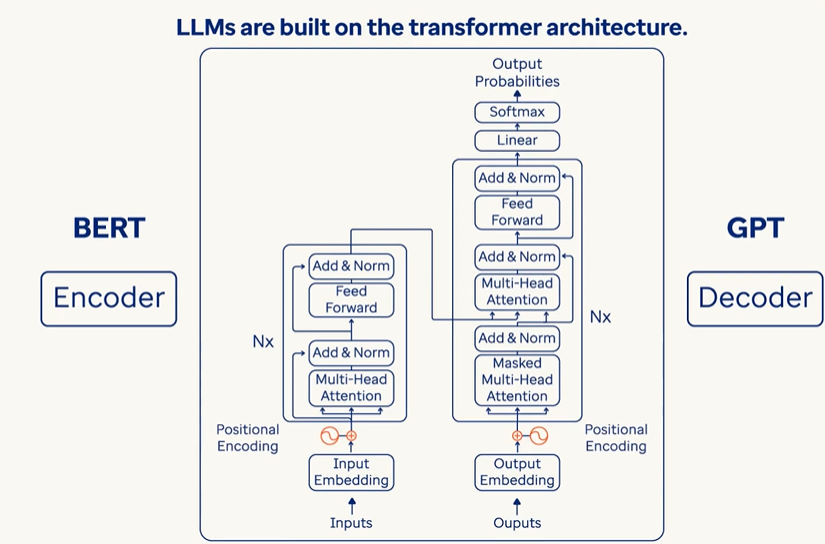
* Every node is connected to others in the next layer.
* Each connection has a **weight**—a number that shows how important that connection is.
* During training, the network **adjusts these weights** to improve accuracy.
* For example, if “apartment size” is very important, its connection will have a **higher weight**.

Training the Network – Learning from Data

* The network learns by comparing its output to the correct answer and adjusting weights.This process is called **backpropagation**.
* Over time, the network learns which features are most important and how to combine them.

## LARGE LANGUAGE MODELS(LLMs)

* LLMs are built on transformation architecture

  
TRANSFORMER ARCHITECTURE

The **Transformer** is the core architecture behind most modern LLMs. It consists of two main parts:

1. ENCODER STACK
2. DECODER STACK

### HOW ENCODERS FIT IN?

The **encoder** in a Transformer:

* Takes an input sequence (like a sentence).
* Processes it through **self-attention** to understand relationships between words.
* Outputs a **contextualized representation** of each token.

✅ Used in models like **BERT**, which are **encoder-only** and great for understanding tasks (e.g., classification, question answering).

#### EXAMPLE

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Let’s walk through a **simple example** to explain how the **encoder** in a Transformer works:  Input Sentence**: "The cat sat."**  Step 1: TOKENIZATION: The sentence is split into tokens: ["The", "cat", "sat"]  Step 2: Embedding + Positional Encoding : Each token is converted into a vector (embedding), and positional information is added so the model knows the order:  "The" → [0.1, 0.3, ...]  "cat" → [0.5, 0.2, ...]  "sat" → [0.4, 0.7, ...]  Step 3: Self-Attention : Now the encoder applies **self-attention**, which allows each word to "look at" the others and understand context.  For example:   * "cat" might attend to "The" to understand it's a subject. * "sat" might attend to "cat" to understand who is doing the action.   This step helps the model understand relationships like:   * Subject → "cat" * Verb → "sat" * Article → "The"   Step 4: Contextualized Representations : After self-attention and feed-forward layers, each token now has a **context-aware vector**:   |  |  | | --- | --- | | Token | Contextualized Vector (simplified) | | "The" | [0.12, 0.45, …] (knows it's an article for "cat") | | "cat" | [0.67, 0.88, …] (knows it's the subject of "sat") | | "sat" | [0.91, 0.34, …] (knows it's the action done by "cat") |   These vectors are the **encoder's output** — they’re like smart embeddings that understand the sentence structure and meaning. |

### HOW DECODERS FIT IN?

The **decoder** in a Transformer:

* Takes the encoder's output (if present) and previously generated tokens.
* Uses **masked self-attention** to prevent peeking ahead.
* Uses **encoder-decoder attention** to focus on relevant input parts.

Outputs the next token in a sequence.

✅ Used in models like **GPT**, which are **decoder-only** and great for **text generation**.

#### EXAMPLE

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Let’s continue with the same example sentence: **"The cat sat."** Now imagine we want the Transformer to **generate this sentence** using the **decoder**.  Step 1: Input from Encoder  The **encoder** has already processed the sentence and produced **contextualized representations** for:   * "The" → [0.12, 0.45, ...] * "cat" → [0.67, 0.88, ...] * "sat" → [0.91, 0.34, ...]   These are passed to the **decoder**.  Step 2: Start Token   * The decoder begins with a special token like <START> to initiate generation.   Step 3: Masked Self-Attention  The decoder uses **masked self-attention** to look only at **previous tokens**, not future ones. This prevents it from "cheating" by seeing the full sentence ahead of time.  Example:   * At first step, it only sees <START> * At second step, it sees <START>, "The" * At third step, it sees <START>, "The", "cat" * And so on…   Step 4: Encoder-Decoder Attention  At each step, the decoder **attends to the encoder's output** to understand the context of the input sentence.  Example:   * When generating "cat", it looks at the encoder's representation of "The" and "cat" * When generating "sat", it attends to "The", "cat", and their relationships   Step 5: Output Token  The decoder predicts the next token in the sequence:   * <START> → "The" * "The" → "cat" * "cat" → "sat" * "sat" → <END>   Each prediction is based on:   * Previously generated tokens * Encoder's contextual output * Attention mechanisms   **Summary in Context of "The cat sat."**   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Step | Decoder Input | Masked Self-Attention | Encoder-Decoder Attention | Output | | 1 | <START> | Only <START> | Looks at encoder output | "The" | | 2 | <START> The | <START>, "The" | Looks at encoder output | "cat" | | 3 | <START> The cat | All previous tokens | Looks at encoder output | "sat" | |

Encoder-Decoder Together

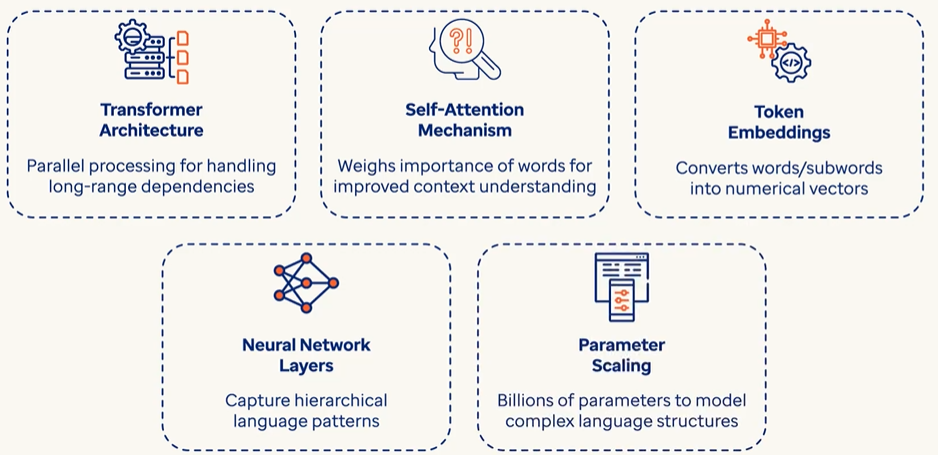
In full **Transformer models** (like **T5**, **BART**, or **original Transformer for translation**):

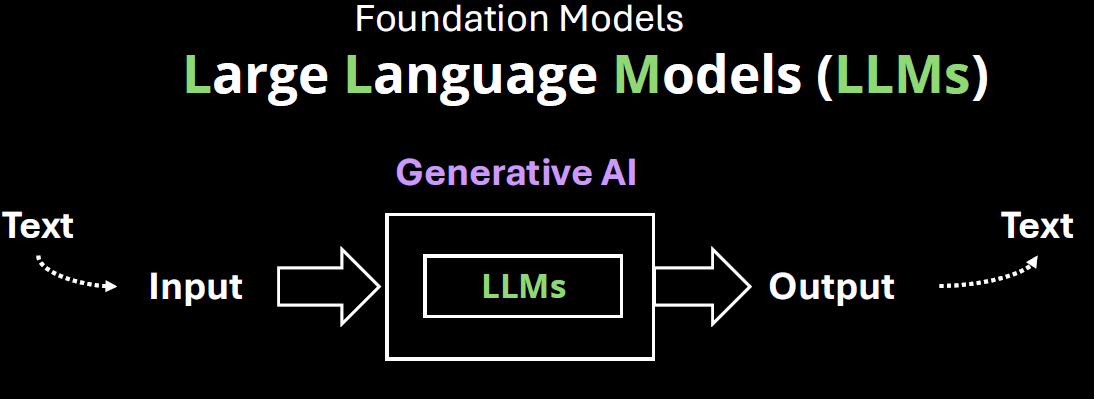
* The **encoder** reads the input (e.g., English sentence).
* The **decoder** generates the output (e.g., French translation), attending to the encoder's output.

LLM Variants Based on Transformer

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model Type | Uses Encoder | Uses Decoder | Example Models | Best For |
| Encoder-only | ✅ Yes | ❌ No | BERT, RoBERTa | Understanding tasks |
| Decoder-only | ❌ No | ✅ Yes | GPT-2, GPT-3, GPT-4 | Text generation, chat |
| Encoder-Decoder | ✅ Yes | ✅ Yes | T5, BART, Marian | Translation, summarization |

### CORE COMPONENTS OF LLMs





* LLMs are AI models designed to understand and generate human-like text.
* Unlike general generative AI (which handles text, images, audio, video, etc.), **LLMs deal exclusively with text—words, grammar, sentences, and contextual understanding.** Example: **ChatGPT**, **GPT-4**, **Claude**, **Gemini**, and **LLaMA**

### HOW LLMS WORK

A diagram of a network

AI-generated content may be incorrect.

1. Training Phase

* The LLM is trained using **self-supervised learning**: it learns by predicting **missing words** in a sentence.
* For example: "The cat sat on the \_\_\_." → Model tries to guess "mat".
* It sees **billions or trillions of words** from diverse sources, learning grammar, facts, reasoning patterns, and even some coding skills.

2. Tokenization

* Text is broken down into **tokens** (which may be words, subwords, or characters).
* For example, “ChatGPT is smart” → ["Chat", "G", "PT", "is", "smart"].

3. Transformer Architecture

* A special deep learning model that uses **attention mechanisms** to understand the context of each word in relation to others in the sentence.
* For example, it knows the word “bank” can mean money or river, depending on context.

4. Inference (When You Use It)

* When you type a prompt, the LLM:
  + Converts your input into tokens.
  + Uses its trained model to predict the **next best token**.
  + Repeats until it completes a meaningful output.
* This happens very fast — like autocomplete on steroids.

What Can LLMs Do?

* Answering questions
* Write essays, emails, or stories
* Translate languages
* Generate code
* Summarize documents
* Act as chatbots
* Reason through logic puzzles (to some extent)

Examples of LLMs

|  |  |  |
| --- | --- | --- |
| **Model** | **Organization** | **Key Use** |
| GPT-4 | OpenAI | General purpose, ChatGPT |
| Claude | Anthropic | Helpful assistant, safety-focused |
| Gemini | Google | Multimodal AI |
| LLaMA | Meta | Open-source, research-focused |

Why it feels like LLMs are answering questions

* It feels like an LLM is answering questions because it has learned to predict the next token in a way that mimics intelligent responses — by learning patterns from millions of real questions and answers.

|  |  |  |
| --- | --- | --- |
| When we ask:  > "What is the capital of France?" | The model sees a familiar pattern. It has seen many examples like this during training:  Q: What is the capital of France?  A: Paris  Q: What is the capital of Germany?  A: Berlin | So, it has learned that when someone types:  > "What is the capital of \_\_\_?"  The best next tokens are usually:  > " [Country name]" → "?" → " A: [Capital]"  So it predicts:  " Paris"   * That’s it. It doesn’t "know" what Paris is — it just has seen that people answer that question with “Paris” so many times that it becomes the most likely token sequence. |
| **Chain of Tokens Feels Like Thought**  Let’s say we ask:  > "Can you explain black holes?" | It starts predicting:  "Sure! A black hole is a region in space..."  Then it keeps going with:  "...where gravity is so strong that not even light can escape..."   * Each time, it's predicting the next most likely token, based on what it has already said and what it's seen in similar explanations before. | * This sequence of predictions sounds natural, structured, and smart — because it's imitating how humans write or speak. * It's Like a Super Autocomplete |

Analogy: The Super Parrot with a Giant Memory

Imagine a **super parrot** named **GPTy** who has:

1. **Read every book**, website, chat, and textbook ever written.
2. **Doesn’t understand the world**, but **remembers how humans talk** — sentence by sentence.

Now, we ask the parrot: “What is the capital of Japan?"

* GPTy searches its memory and remembers **100,000+ times** someone asked that same question, and people always replied: "Tokyo."
* So it just **repeats the most likely answer** it has seen:→ **"Tokyo"**

|  |  |
| --- | --- |
| **Simple Simulation (in Code)**  Let’s simulate a tiny LLM that only learned how to respond to one question:  def tiny\_model(prompt):  if prompt == "What is 2 + 2?":  return "4"  elif prompt.startswith("What is"):  return "I'm not sure, but maybe check a calculator!"  else:  return "Can you ask that again?" | print(tiny\_model("What is 2 + 2?")) # → 4  print(tiny\_model("What is 10 x 10?")) # → "I'm not sure..."  print(tiny\_model("Tell me a joke.")) # → "Can you ask that again?"  That’s basically what a real LLM does — except:   * It doesn't have **if-else** rules. * It has **math-based probabilities** to guess the next best word/token. * It was trained on **terabytes** of data, not 3 lines like our tiny version. |

#### PROMPTS & TOKENS

A diagram of a cream line

AI-generated content may be incorrect.

**WHAT IS A PROMPT?**

* A **prompt** is the **input** we give to a language model — it's the question, instruction, or text we type to get a response. We Think of it like a **conversation starter** or a **command**.It can be a single word, a sentence, or a long paragraph.

**WHAT IS A TOKEN?**

* A **token** is a **chunk of text** — usually a word or part of a word — that the model processes. It is numerical representation (converted by Tokenizer)of word or parts of word , phrases or a character
* Tokens can be as short as one character or as long as one word.
* For example:
  + "ChatGPT" → 1 token
  + "unbelievable" → might be split into ["un", "believ", "able"] → 3 tokens
  + "I am happy." → 4 tokens (["I", " am", " happy", "."])
* Most models (like GPT-4) use a tokenizer to split text into tokens. The number of tokens affects:
  + **Cost** (for API usage)
  + **Speed**
  + **Context limit** (e.g., GPT-4-turbo can handle up to 128k tokens)

|  |
| --- |
| * The set of all tokens used by the model is called the vocabulary of the model * The process of splitting text into tokens is called tokenization. |

**TOKENS IN CHAT GPT**

|  |  |
| --- | --- |
| A screenshot of a computer  AI-generated content may be incorrect. | Open the URL: <https://platform.openai.com/tokenizer>  Enter the desired prompt  It will show how many has been created for a given prompt along with attention score (based on color code)  Note : Each model tokenize the prompt differently as they use different tokenizers |

##### TOTAL TOKENS

* Tokens are numerical representation of characters, words or phrases

|  |
| --- |
| * Tokens are a fundamental metric for measuring usage in an AI system. * **Total tokens = Input tokens (**The number of tokens in the prompt or message you send**) + Output tokens(**The number of tokens in the model's response**)**   . **WHY IT MATTERS?**   * Language models have a **token limit** per interaction (e.g., 8,000 or 32,000 tokens depending on the model). * If the total number of tokens exceeds the limit, the model may truncate the input or fail to generate a complete response. |

##### CONTEXT WINDOW

A row of blue circles

AI-generated content may be incorrect.

* The context window refers to the maximum number of tokens (input + output) that the model can "see" or process at one time.
* The context window includes:
  + **Your input (prompt, messages, instructions)**
  + **The model’s output (response)**
  + **Any previous conversation history (if it's part of the current session)**
* Different models have different context window sizes. For example:
  + GPT-3.5: ~4,096 tokens
  + GPT-4 (standard): ~8,192 tokens
  + GPT-4 Turbo: up to 128,000 tokens

**WHY DO IT MATTERS?**

A black background with white lines and yellow text

AI-generated content may be incorrect.

* If the conversation exceeds the context window, older parts of the conversation may be truncated or forgotten.
* This affects the model’s ability to maintain long-term coherence or remember earlier details.
* For example, a LLM with context window of 10K, which is fed by an article of 15K token – it will truncate the token after 10K tokens of the Article. Hence the long documents may need to be chunked to fit within the context window of the LLM

### MODEL TYPES (LLM TYPES)

#### CLASSIFICATION BASED ON – HOW THEY ARE TRAINED

A diagram of a software development process

AI-generated content may be incorrect.

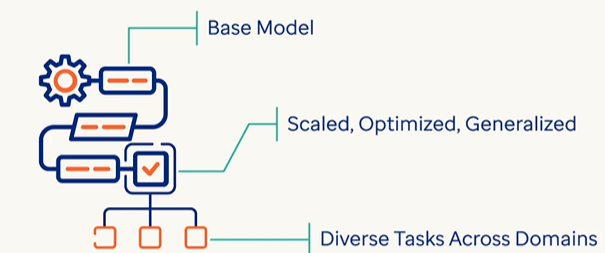
BASE MODEL

|  |  |
| --- | --- |
|  | * Base MODEL: The base model is outcome of pre-training phase on a large corpus of text using self-supervised learning (e.g., predicting the next word). * These models can process language but not optimized for further adaptation. |

|  |
| --- |
| * Self-supervised learning is a type of machine learning where a model learns from unlabeled data by creating its own labels from the data itself.   **HOW IT WORKS**  Imagine a sentence:  "The cat sat on the \_\_\_."  The model is trained to predict the missing word ("mat") using the rest of the sentence. No human labeled this data — the model learns by solving puzzles it creates from raw text.  **KEY FEATURES:**   * No manual labeling needed. * The model learns patterns, grammar, and meaning from large text corpora. * Used heavily in training base models like BERT, GPT, etc. |

* + Purpose: Learns general language patterns, grammar, facts, and reasoning.
  + Example: GPT-3 before any fine-tuning.
  + Limitation: Not optimized for specific tasks or instructions.

Foundational Model



* A broader term that includes base models and other large-scale models trained on diverse data.
* Built on base model – which are scaled , optimized for multitask adaptability
* It can perform diverse task across multiple domains without requiring task specific training.
  + Purpose: Acts as a foundation for building more specialized models.
  + Example: PaLM, GPT-4, LLaMA—used as starting points for downstream tasks.
  + Note: All base models are foundational, but not all foundational models are used as-is.

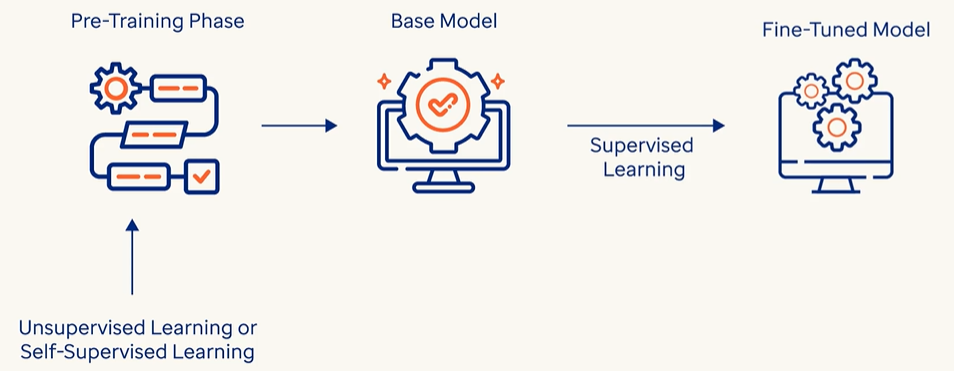
Instruction-Tuned MODEL



* A foundational or base model further trained to follow natural language instructions.
  + Purpose: Makes the model more helpful, safe, and aligned with human intent.
  + How: Trained on datasets like “prompt → response” pairs.
  + Example: InstructGPT, ChatGPT.

Fine-Tuned Model

* A model adapted to perform specific tasks or domains (e.g., legal, medical, customer support).
* The base model is further tuned using dataset using supervised learning.

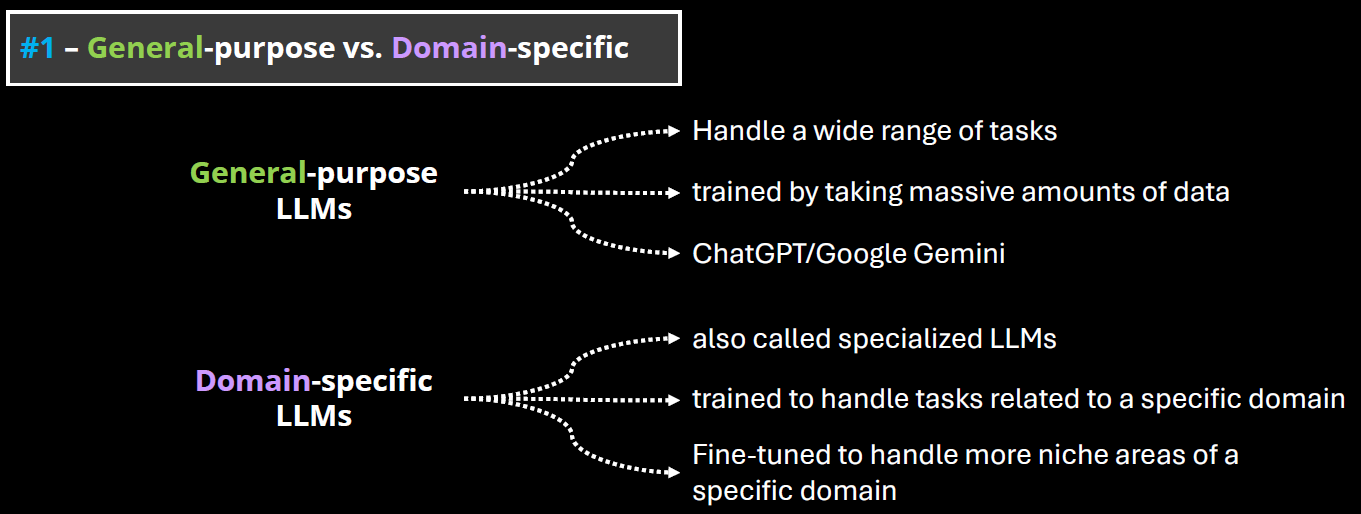


* Purpose: Improves performance on narrow use cases.
* How: Trained on labeled data or domain-specific examples.
* Example: A GPT model fine-tuned for legal document summarization.

#### CLASSIFICATION BASED ON – HOW THEY ARE USED

##### GENERAL PURPOSE AND DOMAIN-SPECIFIC LLMS

The distinction between General Purpose LLMs and Domain-Specific LLMs lies in their training data, capabilities, and intended use cases.:



###### GENERAL PURPOSE LLMS

* These are large language models trained on a broad and diverse dataset that spans many domains (e.g., science, literature, law, medicine, pop culture, etc.).
* Examples: GPT-4, Claude, Google Gemini, LLaMA.
* Strengths:
  + Versatility: Can handle a wide range of tasks (e.g., summarization, translation, coding, creative writing).
  + Adaptability: Can generalize well across different topics and user needs.
  + Scalability: Useful in applications where domain-specific knowledge is not required.
* Limitations: May lack deep expertise in specialized fields.

###### DOMAIN-SPECIFIC LLMS

* These are LLMs trained or fine-tuned on specialized datasets from a particular field (e.g., legal, medical, financial, scientific).
* Examples: Med-PaLM (medical), FinGPT (finance), BioGPT (biomedical), Legal-BERT (legal texts)
* Strengths:
  + High accuracy in domain-specific tasks.
  + Better understanding of terminology, context, and nuances in the field.
  + Often used in regulated industries where precision is critical.
* Limitations:
  + Limited generalization outside their domain.
  + May require frequent updates to stay current with domain knowledge.
  + Less flexible for multi-domain tasks.

##### OPEN AND CLOSED SOURCE LLMs

**The distinction between Open-Source and Closed-Source LLMs revolves around accessibility, transparency, control, and community involvement.**

**A diagram of a source

AI-generated content may be incorrect.**

###### OPEN-SOURCE LLMS

* These models have their code, weights, and training data (or methodology) publicly available. Anyone can inspect, modify, or fine-tune them.
* Examples: Meta’s LLaMA (e.g., LLaMA 2, LLaMA 3), Mistral, Falcon,OpenChat, BLOOM (by BigScience)

CLOSED-SOURCE LLMS

* These models are proprietary. The model weights, training data, and architecture details are not publicly available.
* Examples: OpenAI’s GPT-4, Anthropic’s Claude, Google’s Gemini, , Cohere Command R+,Amazon Titan

### EMBEDDINGS IN GENERATIVE AI

* Embeddings are numerical representations of text—a way to convert words into numbers so machines can understand and process them.
* Machines do not inherently understand text; they operate using numbers. Embeddings allow machine learning models to interpret meaning, context, and relationships between words.

**KEY FUNCTIONALITY OF EMBEDDINGS**

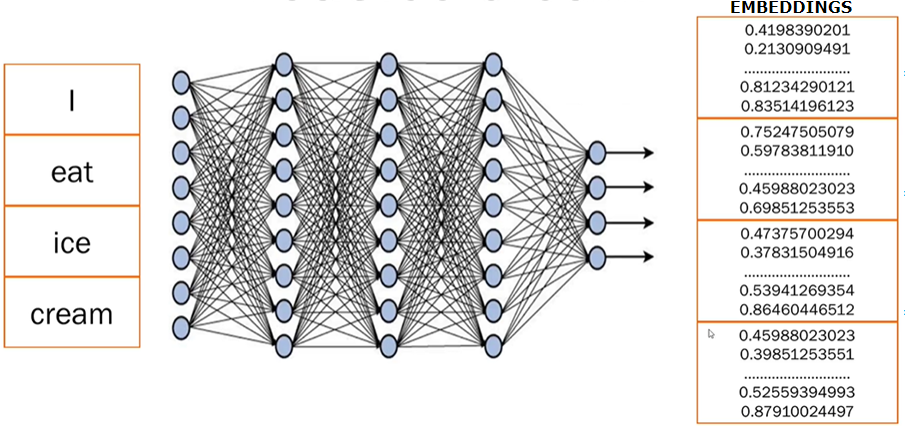
1. **CAPTURING MEANING**: Embeddings reflect the semantic meaning of words or sentences.
2. **CONTEXT UNDERSTANDING**: Embeddings account for the context of text (e.g., same word in different sentences/sentiments - “great” in sarcasm vs happiness).



1. **RELATIONSHIPS**:

* Words with strong associations (e.g., "ice" and "cream") have similar embeddings, reflecting their connection.
* Models understand the proximity and sequence of words based on embeddings.

**HOW EMBEDDINGS ARE GENERATED**



1. **STEP 1:** **BREAKING TEXT INTO TOKENS**

* Sentences are broken into smaller pieces or tokens (e.g., splitting "I eat ice cream" into 4 tokens—"I", "eat", "ice", "cream").

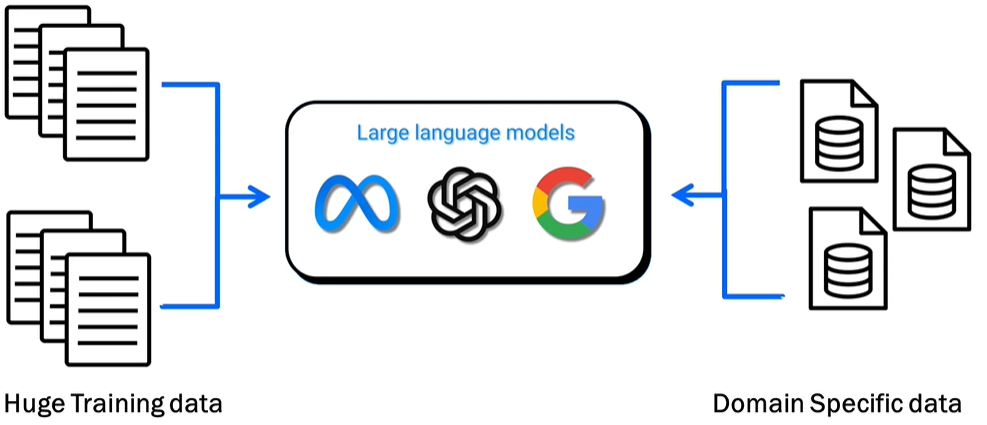
2. **STEP 2: NEURAL NETWORK PROCESSING**:

* Trained **transformer models** analyze the text, generate embeddings, and capture meaning, context, and relations between tokens.

1. **STEP 3: NUMERICAL EMBEDDINGS:**

* Each token is converted into numerical data (random numbers).
* These numbers represent embeddings, storing all learned information about the word or sentence.
* Only the transformer model understands what these embeddings mean based on its training.

### FINE TUNING



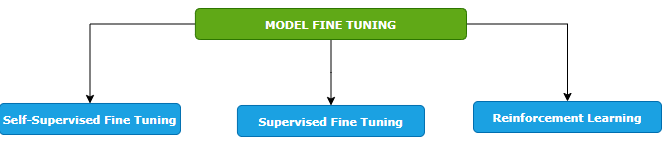
WHAT IS FINE TUNING

* Adjusting a pre-trained large language model (LLM) to provide better results on specific tasks or domain-specific datasets (e.g., healthcare, finance, etc.).

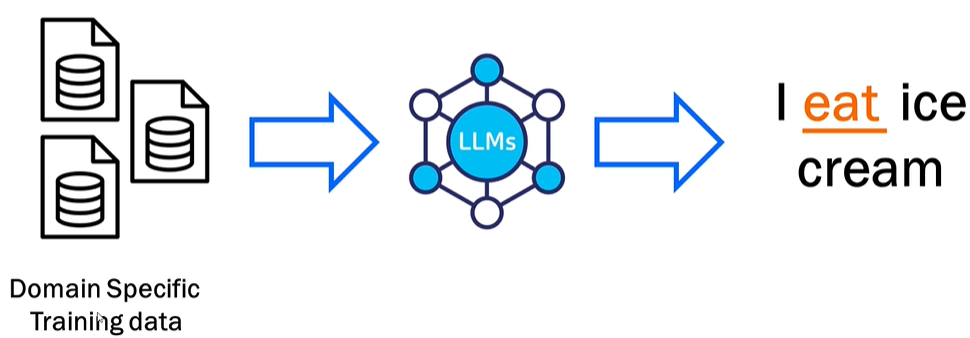
WHAT IS THE PURPOSE OF FINE TUNING

* Enhance the model's ability to generate focused and precise results on specialized datasets.
* Example: Fine-tuning an LLM on medical data improves its accuracy in answering medical queries compared to a general-purpose/pre-trained model.

#### DIFFERENT WAYS TO FINE TUNNING A MODEL



##### SELF-SUPERVISED FINE TUNING



* Training the model on a domain-specific dataset. Means – we give the foundation model a big pile of training data that is specific to our domain, and the model will learn from it. In this way, the model learns to predict missing pieces of data.
* Example - when we say I ice cream, the model predicts that the missing word is eat.
* This is like how the foundation model is trained but the key difference here is that we are fine tuning the model by providing the domain specific data set. Example - Like if we want to train it on health care data set, we will pass it - the drug structure, scientific studies, all the documents that are related to drug and the model will learn from it and it would be able to generate content based on that.

##### SUPERVISED FINE TUNING

A screenshot of a computer

AI-generated content may be incorrect.

* The model is trained using a labeled dataset where both inputs and outputs are provided.
* Example: Input: "How do I find a broken bone?" → Output: "X-ray."
* Helps the model learn more precise responses based on labeled data.

##### REINFORCEMENT LEARNING

|  |  |
| --- | --- |
| A blue arrow with black text  AI-generated content may be incorrect. | A blue arrow pointing to a black arrow  AI-generated content may be incorrect. |
| **LOW SCORE FOR BAD RESULT** | **HIGH SCORE FOR GOOD RESULTS** |

* **Feedback-based learning**.
* The model generates outputs, and scores are assigned based on quality (high score for good results, low score for bad results).
* The model learns overtime from the feedback to improve predictions.

##### KEY FEATURES OF FINE TUNING

1. **STARTS FROM A PRE-TRAINED MODEL**: Fine tuning builds on top of a foundation model already trained on large datasets—it does not start from scratch.
2. **REQUIRES DOMAIN-SPECIFIC DATA**: We must provide good-quality, specific data for training tailored to your use case (e.g., drug data for healthcare).
3. **No Universal SOLUTION**: Each task/use case is unique, requiring case-specific implementation and variations.
4. **ITERATIVE PROCESS**: Fine tuning is repetitive and requires multiple cycles of iteration and adjustments for optimal results.